ORIGINAL RESEARCH

Evaluation and Applicability of Tanaka–Johnston and Moyers' Mixed Dentition Analysis for North Indian Population

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Abstract

Background: Mixed dentition arch analysis is an important criterion in determining an orthodontic treatment plan. The development of the Tanaka–Johnston (1974) and Moyers' prediction (1973, 1998) was established on the Northern European population. However, the corroboration of ethnic tooth size variability suggests that prediction approaches based on a single ethnic sample may not be regarded as universal. Very few studies have been done for the Indian population.

Aim and objective: The purpose of the study was done to evaluate the applicability of Tanaka–Johnston and Moyers' mixed dentition analysis in the prediction of mesiodistal width of unerupted canines and premolars for North Indian children.

Settings and design: This cross-sectional study was done on 200 participants (100 males and 100 females) in the Department of Pediatric Dentistry and Orthodontics in the North Indian population.

Materials and methods: A sample of 200 North Indian population within the age group 12–15 years was randomly drawn. Mesiodistal widths of mandibular incisors and canine and premolars in both the arches were measured from the dental casts of the study participants. The sum of the actual mesiodistal widths of maxillary and mandibular canine-premolars segments was compared to those obtained from Tanaka–Johnston equations and Moyers' prediction tables (35th to 85th percentile).

Statistical analysis used: Inferential statistics were performed using unpaired and paired *t*-tests at a significance level of $p < 0.05$.

Results: Moyers' tables over-estimated the widths in maxilla and mandible of males and females at all probability levels ($p < 0.001$) except under-estimation in females mandibular arch only at 35% probability ($p = 0.056$) and at 35% and 50% probability in maxillary arch ($p < 0.001$ and $p = 0.036$, respectively). Tanaka and Johnston equations over-estimated the values in both the jaws of both the genders ($p < 0.001$).

Conclusion: Tanaka–Johnston equations overestimated the values therefore less appropriate to be used in this population; however, Moyers' prediction tables can be used but at different probability levels for both genders.

Keywords: Arch analysis, Mixed dentition, Moyers prediction, North Indian population, Prediction tables, Tanaka Johnson.

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Introduction

The discrepancy between tooth size and arch length is a general problem in dentistry characterized by a lack of coincidence in the anatomical interproximal contact points of erupted teeth. A precise mixed dentition space analysis is one of the key prerequisite in dictating whether the treatment plan involves the guidance of eruption, serial extraction, space management, or just routine follow-ups of the patient.[1–3]

Adequate diagnosis and early treatment of these discrepancies can prevent any complicated future treatments in permanent dentition. Several approaches of predicting the mesiodistal crown widths of unerupted canine and premolars in mixed dentition patients have been proposed in the literature. These methods broadly use three distinct approaches: the direct measurement of the widths of the unerupted permanent canine and first and second premolars from the radiographs;[1–4] the use of tables or regression equations that correlate the mesiodistal dimensions of erupted teeth to the mesiodistal dimensions of unerupted teeth;[5–7] and finally an integrated approach using radiographic computation and the prediction tables.[8–11]

The third approach is considered to be one of the most accurate, but is time-consuming, requires specific equipment, and maybe less practical in many clinical situations.[12,13] Methods based on linear regression analysis (i.e., second approach) like Tanaka and Johnston[7] prediction equations and Moyers' probability tables[6,14] are used extensively as these are straightforward, undemanding, easy to apply, and provide a reasonable degree of accuracy without requiring any special equipment or exposure to radiations.

The development of the Tanaka–Johnston[7] and Moyers' prediction methods[6,14] was established on the statistics derived from populations of Northern European lineage.

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Tanaka–Johnston analysis uses the reference from the four permanent mandibular incisors and establishes a constant and formula-based predictive model of an equation to be applied on each arch. It is a simple and easy method as no radiographs are required. The corroboration of ethnic tooth size variability suggests that prediction approaches based on a single ethnic sample may not be regarded as universal.[15,16] Therefore, it is of the utmost importance that prediction approaches are elucidated relative to the respective ethnic norms since nonobservance of tooth size ethnic variations would render the interpretations of Tanaka–Johnston and the Moyers' prediction methods, misleading and erroneous.

Hence, the study was done to evaluate the application of Tanaka–Johnston and Moyers' mixed dentition analysis for North Indian children.

Materials and Methods

Sample Selection

The study was conducted on dental study casts of 100 males and 100 females (age range: 12–18 years), who met the inclusion criteria in the Department of Pediatric and Preventive Dentistry and Department of Orthodontics.

Sample Size Estimation

The calculation was done using G*Power 3.1 software (Heinrich-Heine-Universität, Düsseldorf, Germany). Using the value of correlation coefficient as 0.77 from a study by Yuen et al.[17] as the maximum value which could be anticipated (Null hypothesis; H_0), and value of correlation coefficient as 0.65 from a study by Tanaka and Johnston[7] which could be minimally anticipated (alternative hypothesis; H_1) the minimum sample required was 178 at a power of 0.90 and α error probability of 0.05.

Ethical Clearance

The study was approved by the institution review board (IRB) (protocol reference number: Pedo/13/280) and the children and their parents were informed about the research and written consent obtained from the parents.

Inclusion Criteria

- Angle's class I molar relationship and no malocclusion.
- No previous history of orthodontic treatment.
- Children who had intact dentition with no grossly carious teeth, multisurface restorations, or significant attrition.
- High-quality impressions which were free of distortions.

Exclusion Criteria

- Children with hypoplastic teeth.
- Children with the presence of any partially erupted or impacted teeth.
- Children with any congenital craniofacial and dental anomalies.
- Interpromixal caries or restorations.
- History of previous orthodontic treatment.

Methods

Impression Procedure

The measured alginate powder (Septodont Healthcare, India) was poured into a clean rubber bowl containing premeasured water. The powder was incorporated into the water by cautious stirring with a metal spatula to avoid air entrapment into the mixture. A strong figure of eight motion was used to swipe against the sides of the rubber bowl (mixing time: 45–60 seconds) to have a complete dissolution. Children were asked to sit upright in the dental chair and impression material was placed in a suitable tray, to be placed in the mouth. The thickness of the alginate impression between the tray and the tissues was at least 3 mm (gelation time: 2–3 minutes). The impression was immediately rinsed under running tap water to remove the excess saliva and disinfected by spraying with 0.5% sodium hypochlorite. The impressions were poured into the dental stone immediately to avoid any errors due to dimensional changes. The stone cast was kept in the impression for at least 30 minutes before the impression was separated from the cast.

Once the anatomic area of the study models was poured, the artistic portion of the study cast was built to form a base over the anatomic portion using rubber bowls.

Measurement of Actual Mesiodistal Tooth Widths

A Vernier caliper, calibrated with a digital micrometer, with a resolution of 0.01 mm and precision of $\pm$0.02 mm, was used to calculate the mesiodistal widths of the following permanent teeth from the study casts directly: mandibular central and lateral incisors, the right maxillary and mandibular canines, and the right maxillary and mandibular first and second premolars.

Mesiodistal crown widths were measured between the two anatomical contact points of each tooth, aligned to the vestibular and occlusal planes as detailed by Jensen et al.2 All the measurements were recorded to the nearest 0.01 mm. The computations for each cast were done twice and compared. If the values differed by $\leq$0.2 mm, they were averaged. However, if the values varied by >0.2 mm, the teeth were re-measured and the mean of the nearest three measurements was taken as the final value.

The intra-examiner variability was verified by repeating the measurements of randomly selected ten pairs of dental casts at 1-week intervals. Measurements of only the right maxillary and mandibular canine and premolars were taken for every study model to standardize the procedure.

The combined mesiodistal widths of four permanent mandibular incisors were used to predict the combined mesiodistal widths of the permanent canine and premolars for both the maxillary and the mandibular arches using Moyers' probability tables[6,14] and Tanaka and Johnston[7] prediction equations.

The Tanaka–Johnston prediction equations were applied to obtain the predicted values for the whole sample population and both genders. As the probability tables proposed by Moyers are separate for males and females, the predictions using these tables were made only for the genders separately and not for the whole population. The predictions were made at all the probability levels from 35th to 85th percentile of Moyers' prediction tables.

Comparison of Actual Measured and Predicted Tooth Widths

The combined mesiodistal widths of mandibular incisors and actual combined mesiodistal widths of the maxillary and mandibular canine-premolar segment were summarized as means and standard deviations. The predicted mesiodistal widths of the permanent canine and premolars obtained from each prediction method were weighed and with the actual values measured from the dental casts, using a graphical presentation and inferential statistical procedures.

Statistical Analysis

Data were entered into a Microsoft Excel spreadsheet and checked for any missing entries. It was analyzed using the Statistical Package for Social Sciences (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA, IBM Corp.). Inferential statistics were performed using unpaired and paired *t*-tests at a significance level of $p < 0.05$. Furthermore, linear regression analysis was performed to formulate new prediction equations to be used for the prediction of mesiodistal widths of unerupted canines and premolars in the North Indian population.

Table 1: Measured mesiodistal widths (in millimeters) of various segments represented as mean (standard deviation)

	Mandibular incisors	*Mandibular (canine + premolars) segment*	*Maxillary (canine + premolars) segment*
Males	22.28 (1.34)	19.87 (1.14)	20.54 (1.19)
Females	21.96 (1.20)	19.87 (1.29)	20.62 (1.19)
Overall	22.12 (1.28)	19.87 (1.22)	20.58 (1.19)
p values*	0.071	0.997	0.653

*Unpaired *t*-test

Results

- There was no statistical difference among actual mesiodistal widths of canine and premolars among the genders (Table 1).
- Moyers' tables over-estimated the widths in maxilla and mandible of males and females at all probability levels ($p < 0.001$) except under-estimation in females mandibular arch at 35% probability ($p = 0.056$) and at 35% and 50% probability in maxillary arch ($p < 0.001$ and $p = 0.036$, respectively) (Table 2).
- Table 3 shows the result obtained using Tanaka and Johnston equations; the predicted mesiodistal widths of canine and premolars were significantly over-estimated in maxilla and mandibles of both males and females ($p < 0.001$).
- Table 4 and Figures 1 to 4 show the new linear regression equations ($y = a + bx$) as derived from the data collected in the present study for males and females separately.
- The difference between actual and predicted width of mandibular or maxillary canine and premolar segments obtained from new regression equations was tested and found to be statistically non-significant (mandible, $p = 0.843$; maxilla, $p = 0.913$ in overall sample) (Table 5).

Discussion

Since major orthodontic treatment decisions are hinged on variations involving only a very few millimeters, it would be an

Table 2: Predicted mesiodistal widths (in millimeters) of maxillary and mandibular canines and premolars segment and the difference between actual mesiodistal widths and predicted mesiodistal widths at different probability levels using Moyers' tables

		Mandibular canine and premolar segment			*Maxillary canine and premolar segment*		
	Probability level	*Predicted mesiodistal width; mean (SD)*	*Difference between actual width and predicted width; mean (SD)*	*p value**	*Predicted mesiodistal width; mean (SD)*	*Difference between actual width and predicted width; mean (SD)*	*p value**
Males	35	20.43 (0.58)	−0.55 (0.96)	<0.001	20.85 (0.69)	−0.31 (0.98)	0.002
	50	20.86 (0.57)	−0.98 (0.96)	<0.001	21.17 (0.69)	−0.63 (0.98)	<0.001
	65	21.32 (0.58)	−1.44 (0.96)	<0.001	21.50 (0.67)	−0.96 (0.98)	<0.001
	75	21.64 (0.57)	−1.76 (0.97)	<0.001	21.77 (0.65)	−1.23 (0.98)	< 0.001
	85	22.04 (0.58)	−2.17 (1.01)	<0.001	22.07 (0.64)	−1.53 (0.98)	<0.001
Females	35	19.66 (0.68)	0.21 (1.11)	0.056	19.99 (0.34)	0.62 (1.06)	<0.001
	50	20.13 (0.67)	−0.26 (1.11)	<0.001	20.39 (0.34)	0.22 (1.06)	0.036
	65	20.60 (0.64)	−0.72 (1.10)	<0.001	20.79 (0.34)	−0.18 (1.06)	0.099
	75	20.94 (0.64)	−1.07 (1.10)	<0.001	21.10 (0.34)	−0.48 (1.05)	<0.001
	85	21.38 (0.63)	−1.50 (1.11)	<0.001	21.46 (0.34)	−0.85 (1.05)	<0.001

*Paired *t*-test
SD, standard deviation

Table 3: Predicted mesiodistal widths (in millimeters) of maxillary and mandibular canines and premolars segment and the difference between actual mesiodistal widths and predicted mesiodistal widths using Tanaka and Johnston equations

	Mandibular canine and premolar segment			*Maxillary canine and premolar segment*		
	Predicted mesiodistal width; mean (SD)	*Difference between actual width and predicted width; mean (SD)*	*p value**	*Predicted mesiodistal width; mean (SD)*	*Difference between actual width and predicted width; mean (SD)*	*p value**
Males	21.63 (0.67)	−1.75 (0.98)	<0.001	22.13 (0.67)	−1.59 (0.96)	<0.001
Females	21.47 (0.61)	−1.60 (1.10)	<0.001	21.97 (0.61)	−1.35 (1.02)	<0.001
Overall	21.55 (0.64)	−1.67 (1.04)	<0.001	22.05 (0.64)	−1.47 (0.99)	<0.001

*Paired *t*-test
SD, standard deviation

Table 4: Correlation coefficients (*r*) between the sum of mesiodistal widths of lower incisors and the sum of mesiodistal widths of the canine-premolar segment and the results of multiple linear regression to formulate a new regression equation for the study population "*x*" represents the independent variable (combined mesiodistal width of mandibular incisors) and "*y*" represents the dependent variables (mesiodistal width of canines and premolars)

Teeth segments	Gender	The correlation coefficient (*r*)	The coefficient of determination (r^2)	Regression coefficient				Standard error of the estimate (SEE)	*p* value	Regression equation ($y = a + bx$)
				A (SE)	95% CI for A	B (SE)	95% CI for B			
Mandibular canines and premolars	Males	0.528	0.279	9.833 (1.643)	6.571–13.094	0.451 (0.074)	0.304–0.597	0.976	<0.001	$y = 9.833 + 0.451x$
	Females	0.517	0.267	7.703 (2.030)	3.676–11.730	0.554 (0.092)	0.371–0.737	1.108	<0.001	$y = 7.703 + 0.554x$
Maxillary canines and premolars	Males	0.597	0.356	8.745 (1.614)	5.542–11.947	0.529 (0.072)	0.386–0.673	0.959	<0.001	$y = 8.745 + 0.529x$
	Females	0.520	0.270	9.324 (1.865)	5.623–13.025	0.514 (0.085)	0.346–0.683	1.020	<0.001	$y = 9.324 + 0.514x$

SE, standard error, CI, confidence interval

advantage for an orthodontist to use the precise method of tooth size prediction as much as possible in a specific population group.[1–3] The early eruption of mandibular incisors, ease of measurement, and little variability in size are some of the advantages of using mandibular incisors to predict the mesiodistal widths of premolars and canines.[10–12] Also, mandibular incisors are the focal points of most space management problems. Hence, these teeth serve as a good predictor variable.[14] Any methodological differences in the dependent variable (combined widths of permanent canine and the two premolars in a quadrant), however, can be ascribed to the predictor (sum of mandibular incisors in this study).[18] This study aimed to examine the ability of the predictor to counterfeit the values of the mesiodistal widths of permanent canine, first and second premolars in one quadrant.

Comparison of Mean Combined Mesiodistal Widths of Mandibular Incisors

Mean combined mesiodistal widths of mandibular incisors were greater in males (22.28 ± 1.34 mm) than in females (21.96 ± 1.20 mm). However, the differences were not statistically significant. This finding is in agreement with some studies[19,20] but in striking contrast to the other studies which found significant differences among the two genders.[21,22]

Estimation by the Moyers' Prediction Tables on Various Percentiles

The Moyers' prediction tables at 50th percentile probability levels overestimated the canine-premolar segment widths in all cases (p value < 0.001) except for the maxillary arch in females at 35% probability ($p < 0.001$) and 50% probability ($p = 0.036$). Similar findings of overestimation at the 50th percentile level in the mandibular arch of males were reported by the study done by other authors as well.[23,24] Results of the present study showed that 35 percentile was more precise than 75th percentile level of probability, as also suggested by Moyers; although, the underestimation at 35th percentile level was also reported by Singh et al.20

Estimation by Tanaka–Johnston Equations

In the present study, the results of the Tanaka–Johnston equations suggested that Tanaka–Johnston equations overestimated the

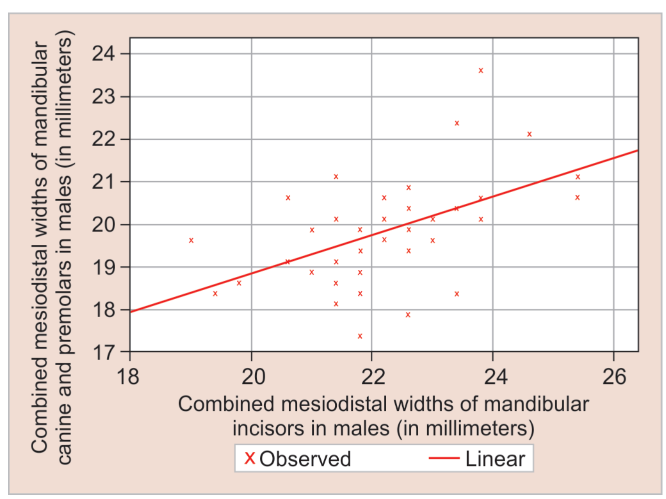

Fig. 1: Linear relationship of the mesiodistal dimensions of the mandibular canine and premolars segment and the mandibular incisors in males

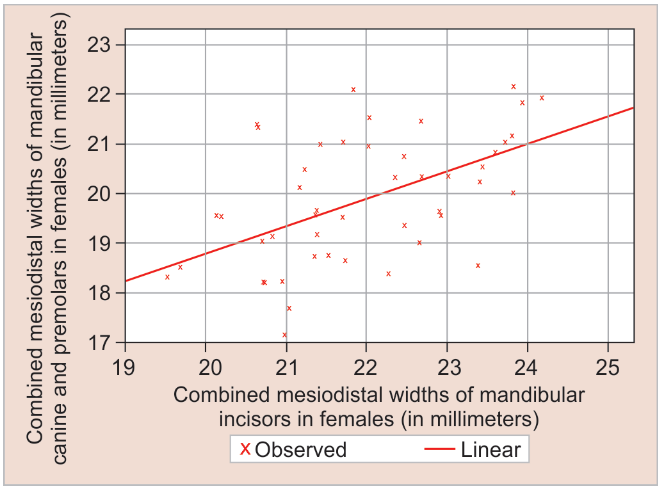

Fig. 2: Linear relationship of the mesiodistal dimensions of the mandibular canine and premolars segment and the mandibular incisors in females

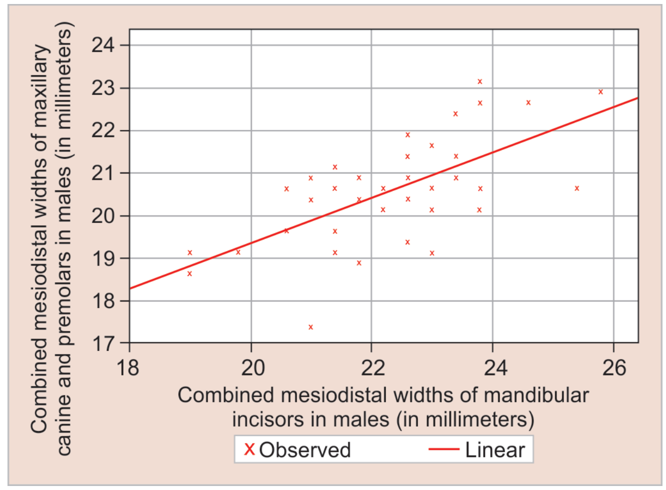

Fig. 3: Linear relationship of the mesiodistal dimensions of the maxillary canine and premolars segment and the mandibular incisors in males

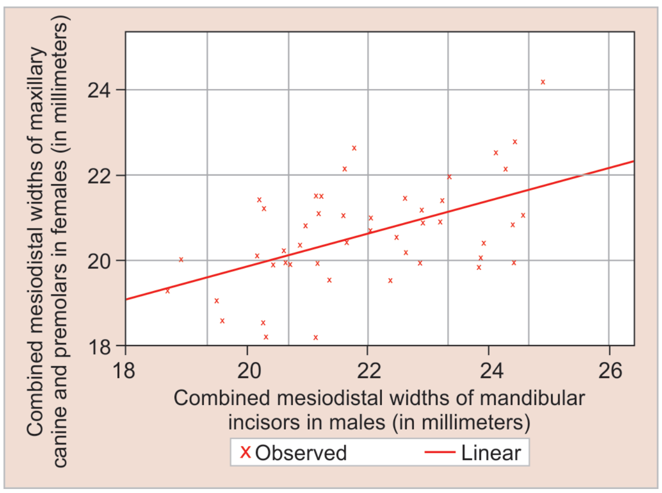

Fig. 4: Linear relationship of the mesiodistal dimensions of the maxillary canine and premolars segment and the mandibular incisors in females

Table 5: Predicted mesiodistal widths (in millimeters) of maxillary and mandibular canines and premolars segment and the difference between actual mesiodistal widths and predicted mesiodistal widths using new regression equations

	Mandibular canine and premolar segment		*Maxillary canine and premolar segment*	
	Difference between actual width and predicted width; mean (SD)	*p value**	*Difference between actual width and predicted width; mean (SD)*	*p value**
Males	−0.10 (0.97)	0.330	−0.11 (0.95)	0.235
Females	−0.06 (1.10)	0.556	0.13 (1.01)	0.228
Overall	−0.01 (1.04)	0.843	0.01 (0.99)	0.913

*Paired *t*-test
SD standard deviation

actual widths of the erupted teeth and may be therefore unsuitable to be used in the North Indian population. The results of the present study are in agreement with other Indian studies[25,26] and different ethnic groups,[21,27] although under-prediction has also been reported with Tanaka–Johnston equations in Jordanian population.[28]

Prediction Models for Females vs Males

In the present study, the value of the r^2, standard error of estimate, and absolute error all pointed to the fact that the prediction models for females were less accurate than for males. Similar findings have also been observed in Northwest European subjects, 1978[10] and Hong Kong Chinese subjects.[17]

In contrast, Jaroontham and Godfrey[29] found their prediction equations in Thai subjects to be more accurate for females. Permanent teeth may be extracted either or over-retained by an erroneous prediction of tooth sizes. Under-estimation of the mesiodistal tooth widths might result in a prudent clinical approach, while overestimation might tend to amplify the space requirements and result in needless extractions.

Hypothetically, the 50th percentile is used as the approximate in all regression equations since any inaccuracy would be distributed equally in either direction.[6,14,29] To construct new probability levels, the values of the regression coefficients and the standard deviation of the difference were used with an assumption that the regression equations predict the value of *y* at the 50th percentile.[17]

Clinically, the value at the 75th percentile is used as the approximate since more conservation on the under-estimation (crowding) is required than that of on over-estimation (spacing).[6] Notwithstanding, the preferred percentile levels to be used may be dissimilar among clinicians depending on the practice and the experience of the orthodontist.

In an endeavor to improve the accuracy of the measurements taken in the present study, the following strategies were employed:

- The use of digital calipers could greatly aid in reducing eye fatigue and the likelihood of reading error.
- Assessment of intra-examiner variability was done using Dahlberg's formula. Method error showed that differences

between corresponding measurements varied from 0.045 to 0.134 in the maxillary and mandibular arches, respectively.

Consequently, any differences in the mesiodistal dimensions, if observed, would have been a result of the variation of the tooth sizes of the present sample and the prediction techniques examined.

Although regression analysis is used in the mixed dentition analysis, the former assumes that the independent variables are measured without error, it is an unlikely possibility in social and behavioral research.[30] The exactitude of the measurement might depend on the number of factors including the safety of the chosen points, the precision of the measuring instrument, and the method in which the investigator uses it; all of which are the potential area of future research. It may not be achievable to obtain very high accuracy in predictive methods based on the measurements of tooth size on dental casts, though reasonably good prediction can assist an orthodontist in the development of a valid diagnosis.

The results of this study indicate that the Tanaka–Johnston[7] prediction method was not accurate when used in North Indian children. Moyers' prediction tables[6] could be used for mixed dentition analysis in the North Indian children but at different probability levels for males and females. Further research is warranted to evaluate and validate the new prediction equations produced by this study to large groups of North Indian children.

Conclusion

The following conclusions were drawn from the present study:

- Tanaka–Johnston equations overestimated the actual widths of the unerupted canine and premolars in both maxillary and the mandibular arches and may be therefore less appropriate to be used in this population from North India for mixed dentition analysis.
- Moyers' prediction tables could be used for mixed dentition analysis in this population but at different probability levels for males and females. 35th percentile may be appropriate for both males and females in the mandibular arch.
- For the maxillary arch, the 35th percentile is appropriate for males and 50th percentile for females, respectively.
- For higher prediction accuracy, it is recommended that the regression equations presented in the current study be used while performing mixed dentition analysis in similar children.

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